SCHEDULE-INDUCED POLYDIPSIA IN RATS LIVING IN AN OPERANT ENVIRONMENT

MICHAEL R. PETERSEN[1] AND DAVID O. LYON

THE UNIVERSITY OF MICHIGAN AND WESTERN MICHIGAN UNIVERSITY

The effect of variations in interreinforcement interval on the temporal and distributional relation between feeding and drinking was continuously monitored. Rats were housed continuously in an operant chamber in which water was freely available, but lever pressing was required to obtain food (45-mg pellets). Initially, pellets were delivered on a fixed-ratio 1 schedule of reinforcement, which was followed by testing on response-initiated fixed-interval 15-, 30-, and 60-second schedules. The total number of discrete, daily meals (a period in which several pellets were earned in succession) was slightly higher during the fixed-interval schedules than during the fixed-ratio 1, but there was no systematic effect of fixed-interval length on meal frequency. Total water consumption, in contrast, increased dramatically as the interval was lengthened: both subjects consumed two to three times as much water on the fixed-interval 60-second schedule as on the fixed-ratio 1. The increased water consumption was the result of an alteration in the distribution of drinking relative to eating. During the fixed-ratio 1 condition, drinking occurred infrequently following individual food pellets and represented the smallest percentage of total drinking; drinking occurred predominantly just before or after a meal. As the fixed interval was lengthened, however, the frequency of postpellet drinking gradually increased and eventually comprised the largest proportion of daily drinking.

Key words: schedule-induced polydipsia, 24-hr sessions, response-initiated fixed interval, lever press, rats

The intermittent delivery of small portions of food to a food-deprived animal for the completion of a simple response results in the consumption of inordinately large quantities of water from a concurrently available reservoir. The excessive drinking, termed schedule-induced polydipsia by Falk (1961), is typically postprandial: shortly after consuming each bit of food the animal takes a short drink from the water reservoir, followed by resumption of the food-reinforced responding.

Numerous studies detailing the nature of, and conditions engendering polydipsia (see Falk, 1969 for an extensive review) have appeared since Falk's initial report of the phenomenon. Yet, a survey of the literature reveals that with one exception (Schuster and Woods, 1966), the phenomenon has been observed exclusively in animals tested in a single, 1- to 3-hr session per day, during which they received a large portion of their daily food ration.

Collier, Hirsch, and Kanarek (1977) have argued forcefully that operant psychology has for too long confined its analyses to behaviors as they occur during relatively brief experimental sessions, without determining whether the principles developed in this time-constrained context generalize to the same behaviors when they are distributed over a 24-hr period. Since the normal, free-feeding rat characteristically distributes its eating over the 24-hr day into nine to 15 discrete meals (e.g., Balagura and Coscina, 1968; Teitelbaum and Campbell, 1958), it might be argued that forcing the rat to consume the largest portion of its daily allotment of food during a single, restricted period of time imposes a grossly abnormal constraint on the animal's consummatory behavior. Whether polydipsia (or nearly any other unusual behavioral phenomenon) is more than an artifactual byproduct of this ex-

tremely artificial feeding situation remains uncertain. Alternatively, the rat may treat the typical experimental session no differently than a long meal, so that information garnered from a 1- to 3-hr session may be representative of the manner in which the animal would distribute its eating and drinking during any meal. Regardless of which of these formulation appears more tenable, both point to the meager amount of information available with respect to polydipsia in animals studied over a 24-hr period.

The present study determined the relationship between eating and drinking in rats maintained on a 24-hr self-paced feeding program. The program permitted subjects that were continuously housed in an experimental environment equipped with a water reservoir, response lever, and pellet dispenser, to distribute bouts of eating and drinking throughout the day. Aside from species differences, the major distinction between the present experiment and one by Schuster and Woods (1966) is that their monkeys, though totally confined to an operant environment, were permitted the opportunity to respond on reinforcement schedules only during several, experimenter-prescribed, 1-hr intervals spread through the day. The present study allowed animals the opportunity to respond for food at any time. The principal intervention in the current experiment consisted of manipulating the schedule requirements for food-reinforced lever pressing. Altering the schedule of reinforcement permitted a direct manipulation of the spacing between individual pellets within each discrete meal (a multipellet bout of eating) in order to observe its effect on the normal relationship between eating and drinking. The basic objective of the study was to determine whether schedule conditions that engender polydipsia during the typically short experimental session also produce polydipsia in animals permitted to distribute their eating and drinking over a 24-hr period.

METHOD

Subjects

Two male, albino rats approximately 100 to 120 days old and weighing 460 g (Subject R1) and 420 g (Subject R2) were obtained from the Upjohn Corporation's (Kalamazoo, MI) breeding colony.

Apparatus

The 19- by 23- by 29-cm experimental chamber was equipped with a response lever, Gerbrands pellet dispenser, food tray, and metal drinking spout. The front and back walls of the chamber were aluminum and the two remaining walls and ceiling were Plexiglas. The lever was centered on the front wall of the chamber, 8.4 cm above the grid floor, and protruded 1.4 cm into the experimental space. A 3.0- by 3.5-cm opening directly below the response lever permitted access to a recessed food tray. Each depression of the response lever exceeding 0.15 N operated a 28-V dc relay producing an audible feedback click. The water spout (3 mm orifice) was attached to a 300-ml calibrated water reservoir and projected 0.6 cm into the chamber through a circular hole 7.0 cm to the right of the lever and food tray. A drinkometer circuit provided an instantaneous digital record of licks at the water spout.

The chamber proper was contained inside a metal booth lined with acoustic tile. A Sylvania 7.5-W (115 V ac) Nite Lite mounted on the ceiling of the booth provided continuous illumination, and an exhaust fan positioned on top of the booth provided ventilation and some masking noise. The booth temperature and humidity were regulated with an air conditioner, which circulated air through the entire laboratory. The booth was located in a room adjacent to the area containing the electromechanical scheduling and recording equipment. Data were recorded on electrical impulse counters, a Gerbrands cumulative recorder, and an Esterline-Angus multichannel event recorder.

Procedure

Subjects R1 and R2 were tested successively in the same chamber; when R1 completed the experiment, R2 was studied. On receipt from the supplier, the rats were placed in individual cages and were permitted free access to food (Noyes 45-mg standard formula pellets) and water. Total food and water intake in the home cage was monitored daily for 10 consecutive days before the experiment began. At the end of the tenth day, all food was withheld for two days. On the second day of food deprivation an animal was moved to the experimental chamber, in which it lived for the

remainder of the study, and conditioned by the method of successive approximations to press the response lever to receive 45-mg pellets. By imposing a minimum 1-sec delay between successive pellet deliveries during this phase the animals were effectively prevented from accumulating a large number of pellets before eating (cf. Kissileff, 1969; Teitelbaum and Campbell, 1958). Within an hour, each animal learned to press the lever, release it, and move quickly to the food tray to eat the pellet. The animals remained on the fixed-ratio (FR) 1 schedule for several days until a consistent pattern of feeding and drinking emerged. After several days on the FR 1 schedule, the schedule of reinforcement was changed to a response-initiated fixed-interval (FI) schedule with a limited hold equivalent to one-third the duration of the FI. This schedule required that the subject press the lever once to initiate each fixed-interval cycle. The first lever-press after the interval elapsed, but before the limited-hold period expired, produced a food pellet.

With an ordinary FI schedule, once reinforcement becomes available at the end of an interval, it remains available until the next response occurs. The limited-hold feature of the present schedule forced subjects to respond within some definite period of time after the FI expired in order to earn a pellet, thus preventing subjects from responding once and receiving a pellet scheduled by an interval some considerable time earlier. The response-initiation requirement reduced the possibility that any polydipsia could be maintained by adventitious reinforcement (Clark, 1962), since postpellet drinking effectively delayed the onset of the next interval and the availability of the next pellet.

The rats were first exposed to an ascending series of interreinforcement intervals (FR 1, FI 15-, 30-, and 60-sec schedules) followed by a descending series (FI 30-, 15-sec, and FR 1 schedules). Subjects remained in each condition for a minimum of 10 days and were changed to a new value when the water consumption on each of five consecutive days differed by no more than 20% from the mean intake for those five days. These stability criteria for changing conditions were adhered to with one exception: R1 remained on the FR 1 schedule for several additional days because the equipment necessary to arrange the response-initiated, limited-hold FI schedule was not available.

Once each day between 3:00 and 4:00 pm, the animal was removed from the experimental compartment and weighed. About 10 to 15 min were required to clean the drinking spout, water reservoir, and experimental compartment, to replenish the food and water supplies, and to record the data for the previous 24 hr. The houselight remained illuminated throughout the experiment except during the daily maintenance period.

Data Analysis: Quantification of Feeding and Drinking

To quantify the characteristics of eating and drinking episodes, it was necessary to develop objective definitions of those events. The Teitelbaum and Campbell (1958) convention for tallying meals was adopted: a burst of eating was counted as a meal if at least five pellets were earned in succession and the burst was separated from other eating bouts by at least 5 min. The five-pellet minimum was invoked to exclude the isolated, reinforced lever-presses completed while the animal was casually moving about the experimental space during the FR 1 condition. These isolated presses occurred only infrequently; no more than five to seven were typically recorded per day. Under the various FI conditions, virtually all pellets were earned in the discrete, multi-pellet meals. The total number of pellets consumed was computed by taking the difference between the number of pellets earned and the number spilled. Neither animal ever spilled more than five pellets per day.

A drinking bout was counted only if it contained at least 10 licks and terminated with either a pellet delivery or a 1-min pause (cf. Kissileff, 1969). The minimum of 10 licks to define a bout was based on pilot observations that indicated that if the rat licked more than once in initiating a burst, it was likely to lick at least 10 times. This criterion also eliminated from analysis those occasional closures of the drinkometer circuit resulting from inadvertent contact during activities not directly related to drinking (e.g., sniffing about, bumping into the spout, etc.). A drinking bout was considered *preprandial* if it occurred within 10 min, but not sooner than 1 min, before a meal. Bouts that occurred within the period 1 min before and 1 min after a meal were classified

as *prandial*. A bout that occurred within 10 min, but not less than 1 min, following a meal was considered *postprandial*. Drinking that occurred more than 10 min before or after a meal was termed meal-unrelated. On the rare occasions that, according to these criteria, a drink could have been classified as preprandial from one meal *and* postprandial for the just-previous meal, it was analyzed with the meal to which it was nearer in time.

The definitions of the categories of drinking were based on several considerations. First, the use of a 10-min criterion to distinguish meal-related from meal-unrelated drinking was motivated by Kissileff's (1969) observation that in normal animals, 78% of all drinking occurs within 10 min before or after feeding. Second, the decision to fractionate meal-related drinking into three categories followed from the observation that drinking within the 10-min interval before or after a meal could be temporally differentiated into two distinct classes: (a) bouts so closely associated with a meal (within 1 min before or after) that they could probably be considered to have occurred during the meal, or (b) bouts that appeared temporally related to the meal but were somewhat removed (approximately 2 to 10 min before or after).

RESULTS

Table 1 contains the sequence of schedules presented to each subject, the number of sessions conducted with each schedule, and summary measures of several feeding and drinking indices for the different conditions. The feeding and drinking measures presented are mean values for the last five sessions under each condition, and form the data pool for much of the description to follow.

Figure 1 depicts the effect of manipulations of the schedule of reinforcement on the amount of water consumed during successive 24-hr periods for Subject R1 (upper panel) and Subject R2 (lower panel). The day-to-day variability in water consumption was somewhat larger for R1 than R2, yet the different schedule conditions affected total water intake similarly in the two subjects. The mean daily water intake (Table 1, column 9) for R1 and R2 over the final five days on the FR 1 schedule was 34 and 27 ml, respectively. The change from the FR 1 to the FI 15-sec schedule produced a moderate but transient increase in

water consumption. Water intake increased gradually and eventually stabilized during exposure to the FI 30-sec schedule. Introduction of the FI 60-sec schedule resulted in an abrupt increase in drinking for both subjects: relative to drinking observed on the FR 1 schedule, each subject nearly tripled its water intake on the first day of exposure to the FI 60-sec schedule. Re-exposure to the FI 30-, FI 15-sec, and FR 1 schedules resulted in a progressive decrease in water intake. However, comparison of water-intake levels for the first and second exposure to these schedules (Table 1, column 9) suggests a tendency toward hysteresis: the volume of water consumed by each subject during the second exposure to the FI 30-, FI 15-sec, and FR 1 schedules stabilized at consistently higher values than were obtained during the initial exposure to the schedule.

Figure 2 illustrates the effect of the different schedules on the distribution of drinking by plotting the percentage of total drinking bursts classified as preprandial, prandial, postprandial, or meal-unrelated for the final five days on each schedule value. These relative measures were obtained by dividing the mean frequencies of the different types of drinking, contained in columns 4, 5, 6, and 7 of Table 1, by the total number of drinking bouts, from column 8, for each schedule condition. A salient feature of these data is the marked increase in the proportion of drinking bursts classified as prandial (occurred within 1 min before or after a meal) as the scheduled inter-reinforcement interval was lengthened. During the FR 1 condition, very little prandial drinking, 9% and 8% of the total for R1 and R2, respectively, was observed. In fact, the largest portion of daily drinking, 44% and 41% of the total for the two animals, occurred outside of the meal context (plotted in the figure as meal-unrelated). During the FR 1 stage, postprandial drinking proved to be the most frequent of all the types of meal-associated drinking (33% and 30% of the total), followed by preprandial (14% and 19% of total), and prandial drinking. A progressively larger proportion of total drinking was classified as prandial during the successively longer FI schedules, and was accompanied by a sharp drop in the relative incidence of the other three types of drinking.

Figure 3 contains tracings of cumulative records for a single meal for each of the various

Table 1

Summary of various measures of daily eating and drinking under different experimental conditions. All data are means of performance for the final five days of exposure to each schedule: numbers within parentheses are standard deviations computed for those five days.

| (1) Subject	(2) Schedule Order	(3) Sessions	Frequency of Different Types of Drinking					(9) Total Water Intake (ml)	(10) Meal Frequency	(11) Pellets Consumed	(12) Weight (grams)
			(4) Pre-prandial	(5) Prandial	(6) Post-prandial	(7) Meal-Unrelated	(8) Total.				
R1	FR 1	62	2.8(1.5)	1.8(0.8)	6.6(1.1)	8.8(1.9)	20.0(1.6)	33.6(2.4)	9.6(0.5)	538.0(9.7)	580.2(1.1)
	FI 15-sec	22	3.0(1.6)	10.6(.55)	9.8(2.3)	15.8(3.3)	39.2(3.5)	33.8(0.7)	12.2(1.3)	533.0(2.7)	585.2(2.0)
	FI 30-sec	32	2.2(1.1)	36.4(3.3)	6.2(3.3)	7.2(1.6)	52.0(2.6)	49.8(0.8)	11.8(0.9)	509.4(9.9)	600.0(1.4)
	FI 60-sec	31	1.2(0.8)	92.0(10.7)	10.4(3.6)	1.4(0.6)	105.0(14.6)	78.4(5.8)	12.0(1.9)	428.8(5.0)	573.4(1.5)
	FI 30-sec	12	2.2(1.3)	57.4(4.6)	8.0(2.0)	5.8(1.8)	73.4(5.3)	49.2(2.9)	10.8(0.9)	509.4(6.0)	582.2(3.6)
	FI 15-sec	13	2.8(1.9)	28.6(4.0)	6.4(2.0)	11.2(2.7)	49.0(2.2)	40.2(1.3)	10.4(0.9)	515.0(8.7)	600.6(1.9)
	FR 1	15	3.4(1.1)	2.0(1.0)	7.2(1.8)	11.6(1.7)	24.2(3.4)	35.2(1.9)	9.6(1.5)	521.4(4.2)	601.0(2.2)
R2	FR 1	21	3.2(0.9)	1.4(1.1)	5.4(1.7)	6.8(2.1)	16.8(2.9)	27.4(0.5)	11.6(0.5)	464.0(3.7)	419.2(1.9)
	FI 15-sec	19	5.2(1.9)	7.0(2.5)	10.6(2.8)	12.6(1.1)	35.4(4.4)	30.8(1.1)	13.8(0.5)	451.0(5.6)	420.6(0.5)
	FI 30-sec	23	3.2(1.2)	28.6(4.9)	7.6(2.3)	7.6(1.5)	46.8(6.6)	45.6(0.9)	13.6(0.5)	426.2(0.3)	420.2(1.5)
	FI 60-sec	20	1.0(1.3)	74.5(4.4)	13.6(2.8)	1.8(1.8)	91.0(7.4)	74.8(0.8)	14.0(0.7)	378.0(8.0)	391.8(1.9)
	FI 30-sec	15	2.6(0.9)	42.2(.52)	11.8(3.0)	8.6(2.6)	65.2(7.1)	49.6(0.9)	13.2(0.5)	427.4(5.4)	410.8(1.9)
	FI 15-sec	11	5.8(0.8)	17.2(3.3)	8.8(1.5)	10.2(1.8)	42.0(6.3)	34.4(0.5)	12.6(0.5)	452.0(9.1)	413.0(3.1)
	FR 1	11	2.8(1.8)	2.4(1.7)	7.0(1.2)	7.6(1.3)	19.8(4.8)	28.0(0.7)	11.2(0.5)	454.2(5.6)	415.6(3.8)
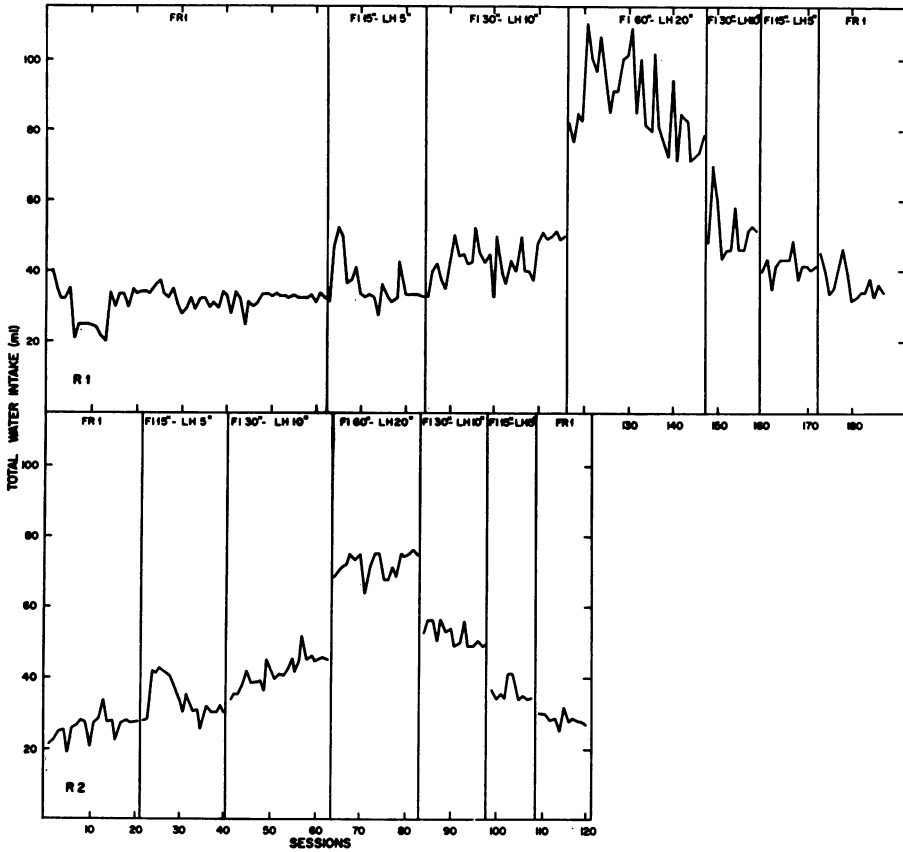
Fig. 1. Total water intake per 24-hr session under the various schedule conditions for Subjects R1 (upper) and R2, (lower). FR 1: fixed-ratio one schedule; FI x sec LH y sec: response-initiated fixed-interval schedule of x sec with limited hold of y sec.

schedule values. The segments shown were selected nonsystematically from records produced during the final five days of the initial exposure to the different schedules. During FR 1, each lever press stepped the cumulative pen upward and produced a diagonal slash on that channel. Under this condition, the cumulative pen reset to baseline following every fiftieth reinforcer. During the FI schedules, lever presses advanced the cumulative pen upward and the pen reset to baseline with each pellet delivery. Diagonal slashes on the upper trace of the FI records were produced when an interval-initiating response occurred. The lower event pen was deflected following every tenth lick at the drinking spout during the FR and FI conditions. The records suggest that the frequency of prandial drinking increased with longer interreinforcement intervals. Moreover, the prandial drinking assumed the familar postpellet pattern characteristic of

polydipsia. Shortly after a pellet was delivered, the animals were frequently observed to consume a small amount of water, followed by resumption of lever pressing. Inspection of daily cumulative records also suggested that as the interreinforcement interval increased, a larger proportion of the pellets was followed by drinking. Figure 4 confirms this latter impression. The figure presents the proportion of individual pellets that were followed within 1 min by a burst of drinking. The final five sessions for initial and replication exposures to each schedule were pooled, so that an overall mean frequency of prandial bouts (Table 1, column 5) and food pellets consumed (Table 1, column 11) could be computed. Finally, each datum point was calculated by dividing the mean number of food pellets into the mean frequency of prandial drinks for each interreinforcement interval. Increasing the interval led to a sharp increase in the probabil-
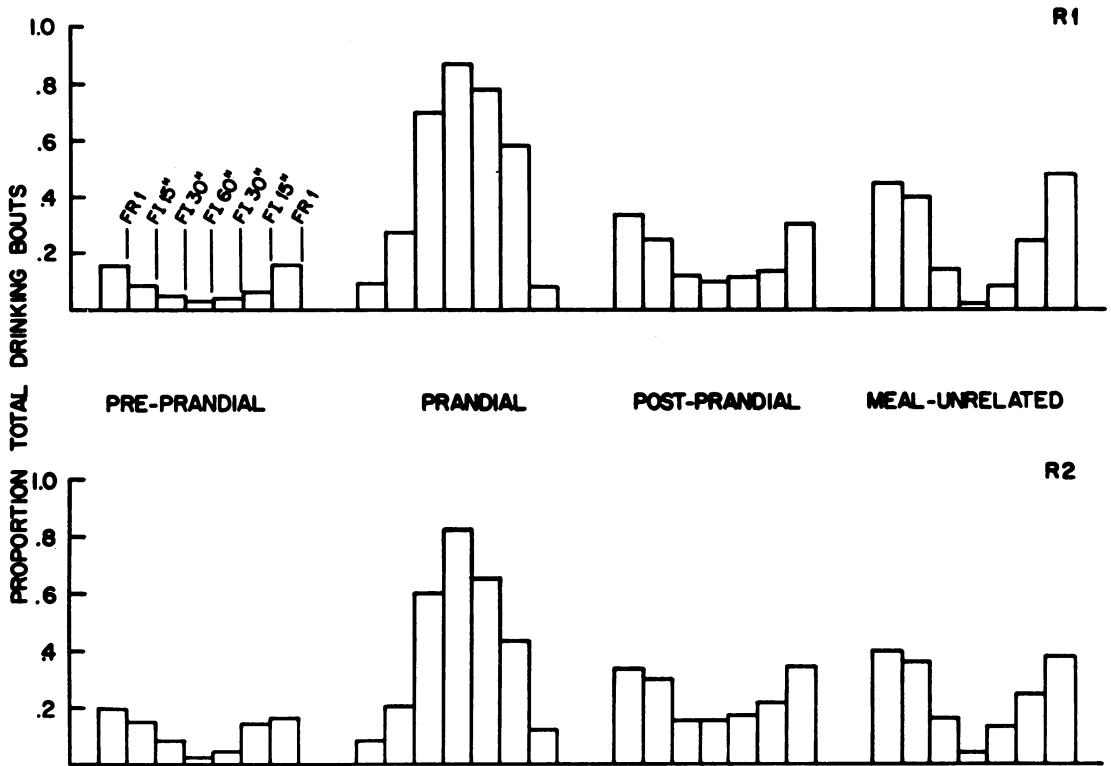
Fig. 2. Distribution of drinking in relation to eating under different schedule conditions for R1 and R2.

ity that receipt of a pellet would be followed by a bout of drinking. During the FR 1 condition, each subject drank following less than 5% of the pellets, whereas about 20% of the pellets received during FI 60-sec ended with a drinking bout.

Figure 5 illustrates for both subjects the effect of the different interreinforcement interval values on three indices of eating: total number of daily meals (top two panels), daily
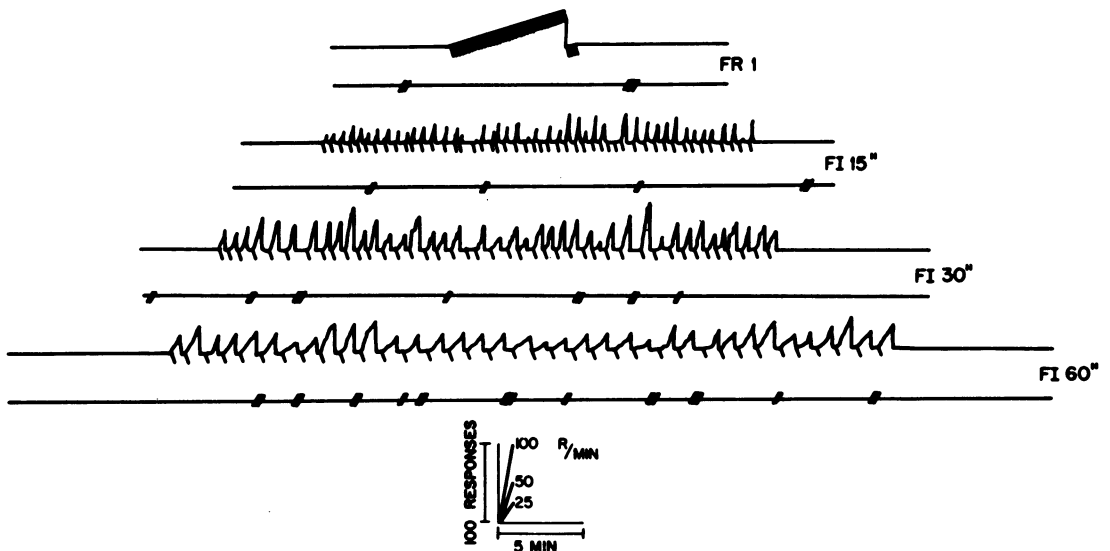

Fig. 3. Tracings of cumulative records of a single meal under different schedule conditions.
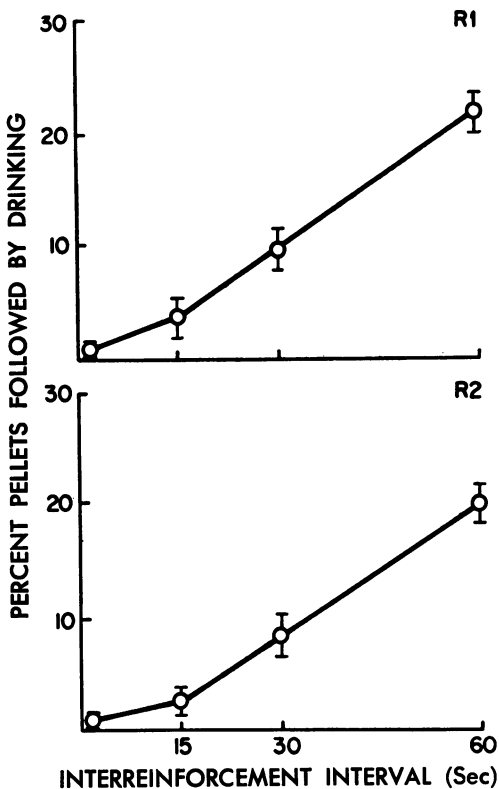
Fig. 4. Percentage of total pellets followed within 1 min by drinking as a function of interreinforcement interval. Data from the FR 1 condition have been plotted over the 1-sec interreinforcement interval. Brackets around each datum point indicate ±1 standard deviation.

food intake (middle two panels), and daily body weight (bottom two panels). The numbers within blocks of the upper two panels are the average number of meals consumed during the final five days of that condition (Table 1, column 10). Over the final five days on the FR 1 schedule, R1 and R2 consumed an average of 9.6 and 11.6 meals per day. Introduction of the FI 15-sec schedule produced an increase in total meal frequency for R1 of 2.6 meals, and for R2 of 2.2 meals. The change to FI 30-sec resulted in no additional increase. In fact, over the last five days, each subject showed a small decrease in average meal frequency. The FI 60-sec schedule also had little discernible effect on meal frequency beyond that observed for the FI 15- and 30-sec schedules for either subject. Re-exposure to the FI 30-, 15-sec, and FR 1 schedules resulted in a steady decrease in meal frequency for both animals to initial exposure levels.

The middle two panels of Figure 5 show the total number of pellets earned daily during the study. Average total pellet consumption (Table 1, column 11) remained approximately constant during the FR 1, FI 15-, and 30-sec conditions but dropped during the FI 60-sec condition by 19% and 18% for R1 and R2, respectively. Interestingly, the lower two panels show that the decrease in food intake was accompanied by only a moderate drop in average body weight (Table 1, column 12) during the FI 60-sec condition. The approximately 4 to 7% weight loss did not become apparent until after several days on FI 60-sec.

Both animals were quite proficient in meeting the requirements of the response-initiated, limited-hold FI schedules. After one day on the schedule, both subjects received a pellet following more than 95% of intervals initiated during each 24-hr period.

DISCUSSION

The present results clearly extend the generality of schedule-induced polydipsia in demonstrating that intermittent reinforcement schedules induce excessive drinking even in animals permitted to distribute their consummatory activity freely over a 24-hr period.

Two aspects, in particular, of the results are consonant with earlier reports. First, the ubiquitous postpellet pattern of polydipsic drinking, reported in more conventional studies, was observed in both animals. Second, total water intake was directly related to length of the interreinforcement interval. This latter finding qualitatively replicates a portion of the ascending limb of the bitonic function relating water intake to interfood interval (Falk, 1966; Flory, 1971; Hawkins, Schrot, Githens, and Everett, 1972). An attempt to produce the descending limb of the bitonic function was judged unfeasible because further increases in the interreinforcement interval beyond 60 sec would have forced the animals to devote a disproportionately large part of the day to earning a near-normal amount of food.

Since meal duration necessarily increased during the longer FI schedules, the finding that a progressively larger proportion of total drinking was classified as prandial during the longer FI schedules might be interpreted as little more than a consequence of an increased opportunity to meet the criteria for prandial
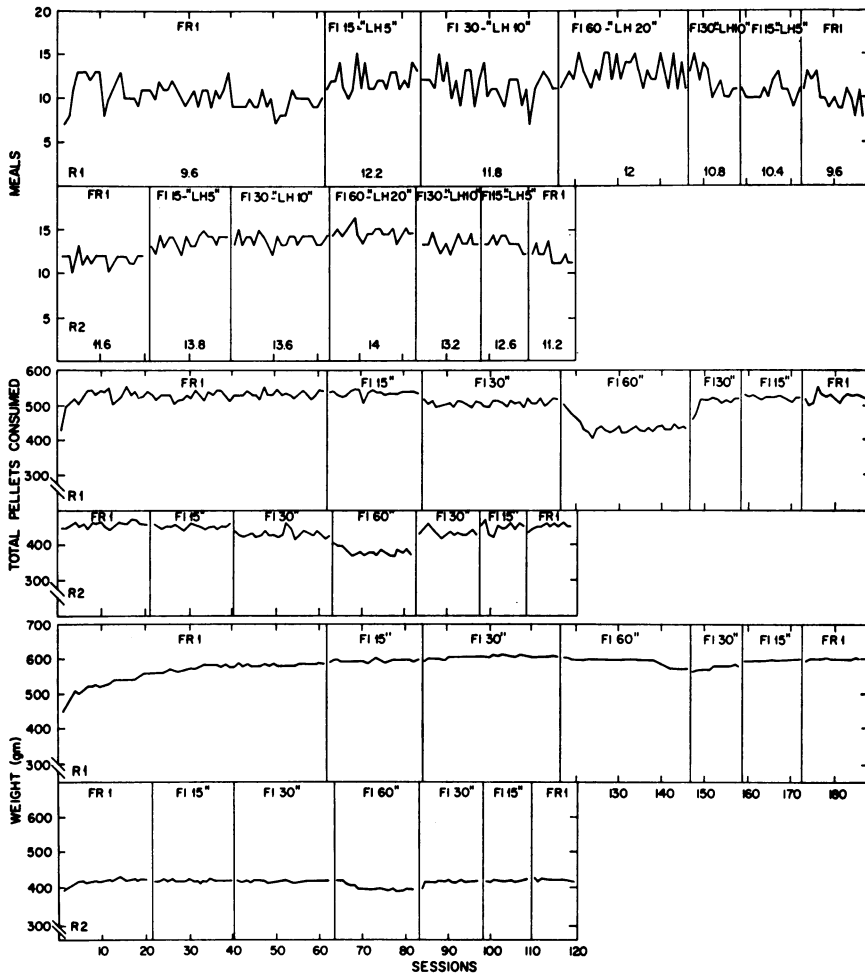
Fig. 5. The effect of interreinforcement interval on three indices of daily feeding behavior: meal frequency (top two panels), pellets consumed (middle two panels), and body weight (bottom two panels). Numbers within blocks in the top two panels indicate mean meal frequency for the final five sessions on that condition.

drinks. This account seems unlikely, given the systematic and close temporal relation between pellet delivery and a drink. More importantly though, the proportional increase in prandial drinking was largely the result of an increase in the total *number* of drinking bouts (Table 1, column 8) during the longer FI schedules, the largest proportion of which were prandial drinks (Table 1, column 5).

One disparity between the present and previous reports concerns the finding that, during the condition that produced maximum drinking (FI 60-sec) only approximately 20% of all pellets were followed by drinking. This is in clear contrast to the usual report that 85 to 95% of all pellets consumed during a 1- to

3-hr session are followed by drinking (Keehn and Colotla, 1971; Segal, Oden, and Deadwyler, 1965). Nonetheless, the total water intake over a 24-hr period within the present experiment approximates that observed over a 3-hr period in some earlier studies (*e.g.*, Falk, 1961). The lack of agreement concerning the percentage of pellets followed by drinking might simply reflect the failure of this experiment to reproduce the food-deprivation conditions generally experienced by polydipsic subjects. In most studies of polydipsia, animals are held at 80 to 85% of their free-feeding body weight, whereas the present subjects maintained themselves at or above 93% of their free-feeding weights during the condition that produced the most drinking (FI 60-

sec). These results seem to suggest that while the likelihood of a postpellet drink increases as the interreinforcement interval is lengthened (see Figure 4), the *maximum* percentage of pellets that will be followed by drinking may actually be a function of absolute deprivation level. This implication appears consistent with Falk's (1969) finding that polydipsia is attentuated as animals approach their free-feeding weights. Unfortunately, Falk reported only changes in the amount of water consumed, without indicating whether the reduction was the result of changes in the probability of drinking or a decrease in the amount consumed per bout (or both). However, it seems reasonable to assume that at least some portion of the reduced consumption was due to a decrease in the proportion of pellets followed by drinking. Another possibility is that the probability of a postpellet drink may be dependent on session length. While the present data might be interpreted as suggesting that longer sessions reduce the likelihood of a postpellet drink, a test of the adequacy of such an account will require systematic variations in session length with other conditions held constant.

A comparison of total water intake (Figure 1) with the daily weight data (Figure 5, lower two panels) for the early sessions of the FI 60-sec condition reveals that the animals acquired polydipsia without any measurable weight loss. Initially, this fact appears at variance with Falk's (1969) demonstration that polydipsia decreases with increases in body weight. However, Falk's experiment was conducted with animals in which polydipsia had already been established. The role of deprivation in the development of polydipsia has not been systematically studied. Interestingly, though, Falk (1969) did report that prefeeding animals up to 45 min before a session produced only a moderate decrease in drinking. Additional research concerning the importance of deprivation conditions for the acquisition and maintenance of polydipsia is clearly in order. Under some circumstances though, it does appear that animals need not be severely deprived to show polydipsia.

During the descending series of fixed intervals, some difficulty was encountered in recapturing the water intake values originally obtained during the ascending series of intervals. Allen and Kenshalo (1976) reported similar difficulties when they exposed rhesus monkeys to an ascending series followed by a descending series of interval values. Taken together, these studies clearly suggest that some sort of sequence effect of indeterminate origin is likely to be observed when the ascending-descending protocol is followed. It is worth noting though, that the basic functional relationship between interreinforcement interval length and amount of polydipsia is robust enough to withstand such order effects: animals continue to drink more when tested with long intervals than when they are exposed to short intervals.

Although observations from only two subjects were reported, the orderly and systematic nature of the within-subject results, and the close agreement between the individual subjects, suggests that two animals were quite sufficient to demonstrate the viability of the 24-hr preparation. Also, the fact that the FI 60-sec condition was not repeated might appear to restrict the generality of the results. However, it is noteworthy that although Falk's (1969) original report of the bitonic relation between water intake and interreinforcement interval length was based on data gathered from a single ascending series of interval values, the basic result has been replicated by investigators using an ascending series alone (Flory, 1971; Hawkins, *et al.*, 1972) and by others employing nonsystematic series of repeated measures at different interval lengths (Allen and Kenshalo, 1976; Bond, 1973; Keehn and Colotla, 1971; Segal, *et al.*, 1965).

Falk (1971) argued that schedule-induced polydipsia should be classified as a displacement activity because it shares so many of the properties of the prototypical displacement activities—the seemingly gratuitous, functionally irrelevant behaviors that often appear in "conflict" situations—described by· ethologists (*e.g.*, Tinbergen, 1952). In this ethologic account, the food-deprived animal drinks excessively because eating is thwarted by the spaced feeding characteristic of intermittent reinforcement schedules. Falk's formulation seems to suggest that the thwarting effectiveness of the feeding schedule derives largely from the animal's food-deprived condition. The present results show, however, that food deprivation is not a necessary condition for the acquisition of polydipsia. Simply imposing an intermittent schedule of reinforcement is

a sufficient thwarting operation to induce polydipsia. With this apparently minor revision, the results of the present study appear consistent with the displacement-activity account.

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